3.12 CLUTTER

Radar signals received from objects other than the target, or clutter, can be a substantial problem for both acquisition and tracking when the target aircraft is at low altitude or in heavy weather. In fact, clutter is the dominant source of interference outside of the receiver, and can seriously limit the ability to detect and track targets with small signatures.

Clutter can be modeled at various levels of fidelity. In a rudimentary fashion, the impact of clutter can be determined as a function of the signal-to-clutter ratio. If the signal-to-clutter ratio falls below some level, then the target can be declared lost in clutter. At a higher level of fidelity, the clutter returns can be propagated through the signal processing circuitry, and they can compete with the target return. The latter methodology is the one employed in ESAMS.

ESAMS addresses the possibility of range ambiguities in the accumulation of clutter returns. At high pulse repetition frequencies (PRFs), the interpulse period is so short that ambiguity occurs regarding which pulse produced the return. It is therefore impossible to "gate out" returns which occur at range intervals of $c/2prf$, where c is the speed of light.

The terrain reflectivity impacting the radar has been quantified by Georgia Tech and Lincoln Laboratory development programs. Georgia Tech has developed models to calculate terrain reflectivity (σ°) which are based upon least squares fit to available low angle clutter data. The basic methodology is illustrated in Figure 3.12-1. This figure shows the different types of terrain data available. For these types, the parameters A, B, C, and D allow clutter magnitudes to be extracted for specific grazing angles of the incident radar energy.

Terrain Types

Sea	Crops	Rocks
Soil	Trees	Urban
Grass	Sand	Wet Snow

$$\sigma^{o} = A(\alpha + C)^{B} e^{-D/1+0.03\sigma_h}$$

α = incidence angle in radians

σ_h = surface standard deviation in cm

FIGURE 3.12-1. Georgia Tech Reflectivity Data (square meters).

The Lincoln Laboratory data is based on a field test program conducted at various locations in Canada. Clutter coefficients are quantified for three generic types of terrain: low rural, high rural, and urban. The backscatter (i.e., clutter) for these types of terrain and their associated cover is based on the radar antenna depression angle.

Associated with these data is a visibility factor that reduces the magnitude of the return based on radar height and distance to the clutter patch. The visibility factor is appropriate to a generic application of either the Georgia Tech or Lincoln Laboratory clutter data. ESAMS allows the user to include this factor with either of the clutter methodologies. The impact of the visibility factor is to provide statistical masking to the clutter and to attenuate its magnitude appropriately. For either the Georgia Tech or Lincoln Lab clutter codes, the terrain patches are broken up into small areas, and the current depression/grazing angles are obtained. The clutter return is the result of aggregating the reflectivity from the various areas.

Clutter rejection circuitry for short-range trackers is presently simulated by a notch filter. The depth of the filter is 25 dB during acquisition and 34 dB during track.

Two clutter routines are available in ESAMS 2.6.2. The baseline, or native, code uses methodology developed by Georgia Tech. This code uses both Georgia Tech and Lincoln Lab reflectivity data. Presently, the native code is only operational with the flat earth model. For a flat area such as that experienced at Eglin AFB, the native code can operate satisfactorily by having the right terrain cover and roughness specified. For other than flat terrain, the recently installed Ground Radar Clutter Estimator (GRACE) can be used.

The GRACE algorithm uses the Lincoln Laboratory methodology imbedded in the ALARM91 model. This routine can be mated with digitized terrain, and it includes the effects of shadowing and curved earth as illustrated in Figures 3.12-2a and 3.12-2b.

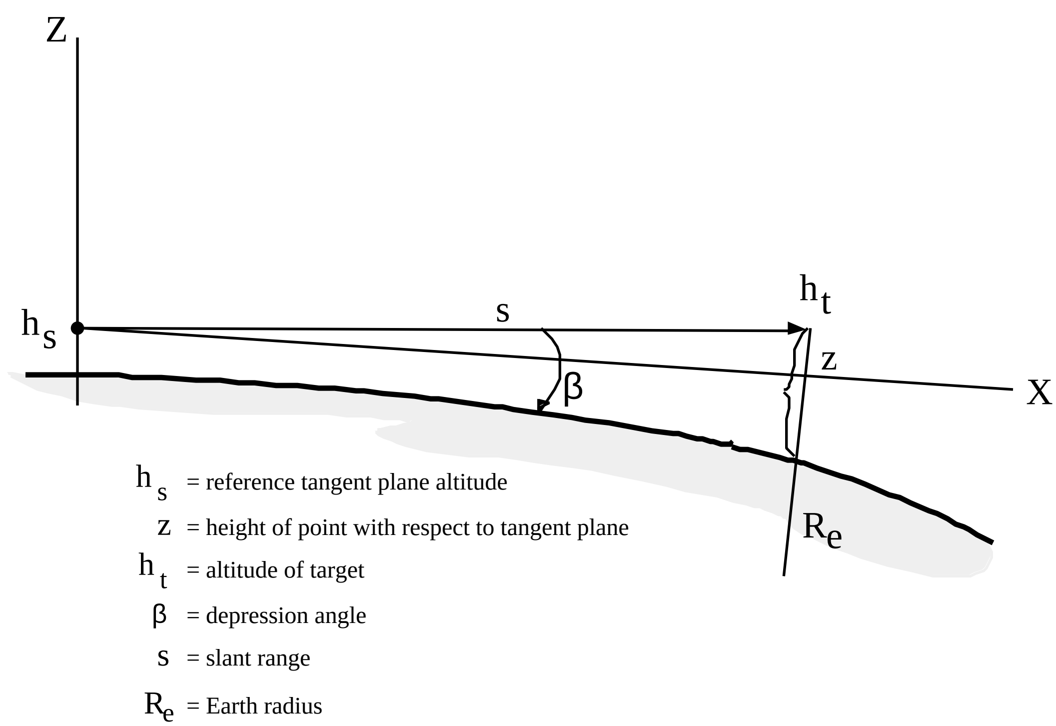

FIGURE 3.12-2a. Spherical Earth Calculations.

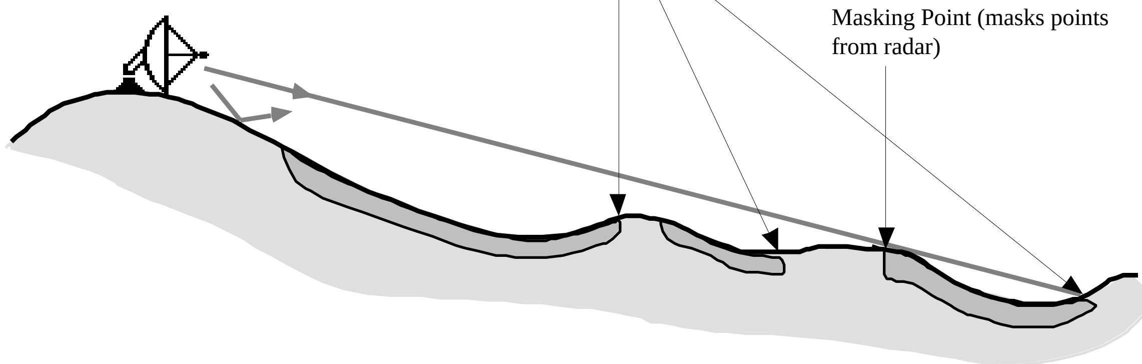

FIGURE 3.12-2b. Illumination and Masking Points.

The equation used in ESAMS to compute clutter power is essentially the radar range equation with the target cross-section replaced by the terrain reflectivity. The terrain reflectivity is determined as the product of a reflection coefficient, σ, times the area of the illuminated ground patch. The range gate width is assumed to be sufficiently small that the antenna gain is constant over the radial integration, however, explicit antenna gain is computed for off-boresight angles in the azimuthal integration. The resolution of the azimuthal integration is determined by a MULC data item, RELEN, the resolution length.

The user can specify different reflectivity coefficients, σ, using the PROGC input TTYPE (terrain type). Data for nine different terrain types at four different frequencies is available.

Once the clutter power has been computed, it is modified to account for (range-dependent) clutter masking. This is done using a fit to empirical masking data published by MIT Lincoln Labs. Resulting clutter power is calculated by:

$$P_C = \frac{P_T \lambda^2 \sigma_o R_g \Delta R_g}{(4\pi)^3 LR^4} I_\theta \qquad [3.12\text{-}1]$$

where

$$I_\theta = \sum_i G^2(\theta_i, \varphi)\Delta\theta_i \ (\textit{Angular Integration}) \qquad [3.12\text{-}2]$$

and

$$\begin{aligned} \Delta\theta_i &= R_\theta / R_g \\ R_\theta & \ (\textit{resolution length}) \end{aligned} \qquad [3.12\text{-}3]$$

Data requirements for assessment of clutter model calculations are listed in table 3.12-1.

TABLE 3.12-1. Clutter Data Requirements.

Data Item		Accuracy	Sample Rate	Comments
2.2.1	Target altitude	±5 m	10 Hz	Above ground level at radar
2.2.2	Clutter RCS/area	±1 dBsm/sm	10 Hz	
2.2.3	Target RCS	±1 dBsm	10 Hz	
2.2.4	Detection range	±50m	SV/T	
2.2.5	Clutter Power	±1 pW	10 Hz	
2.2.6	Antenna elevation angle	±0.1 deg	0.1 deg/step	
2.2.7	Antenna azimuth angle	±0.1 deg	0.1 deg/step	
2.2.8	Target echo	±1 dB	10 Hz	
2.2.9	Receiver noise figure	±1 dB	SV/T	
2.2.12	Terrain cover	n/a	SV/T	
2.2.14	Clutter signal amplitude	10^{-9}W	0.1 deg steps, 0 to 360 deg Az, 0 deg El, range gate step increment to horizon	

3.12.1 Objectives and Procedures

Sensitivity to clutter will be a function of inputs from the various terrain types available and resolution length. Inputs are a function of grazing angles, which are dependent upon target and antenna geometries. Relative effects of changes in these relationships can be examined via multiple errors of ESAMs using different terrain, radar, and target altitude input parameters.

3.12.2 Results

Figure 3.12-3 compares seven clutter reflectivities at grazing angles ranging from 0 to 90 degrees for a radar frequency of 9.5 GHz. Several terrain types use identical data. These are soil, sand, and rocks, and grass and crops. The result is only four distinct terrain types. Of these, the urban terrain type has the highest clutter reflectivity overall. Five db of additional reflectivity can be added to any of the available terrain types by setting the WET flag in the PROGC.

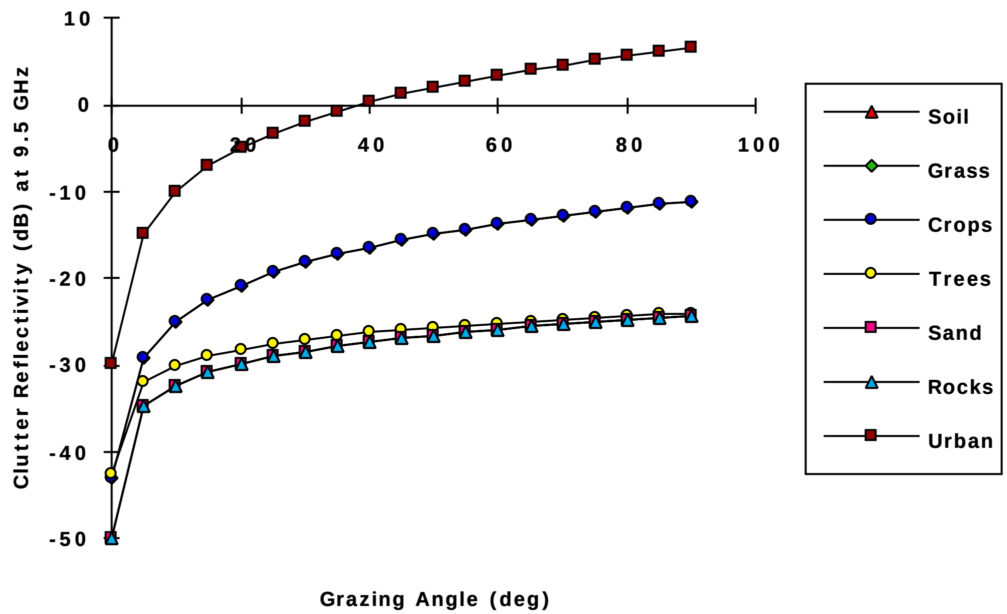

FIGURE 3.12-3. Clutter Reflectivity vs. Terrain Type.

The computed clutter power is sensitive to the resolution length, as illustrated in Figure 3.12-4. Until recently, the default value was 1000 m which resulted in significant numerical error during the angular integration. The current default of 100m yields more accurate results at the price of somewhat longer computational times.

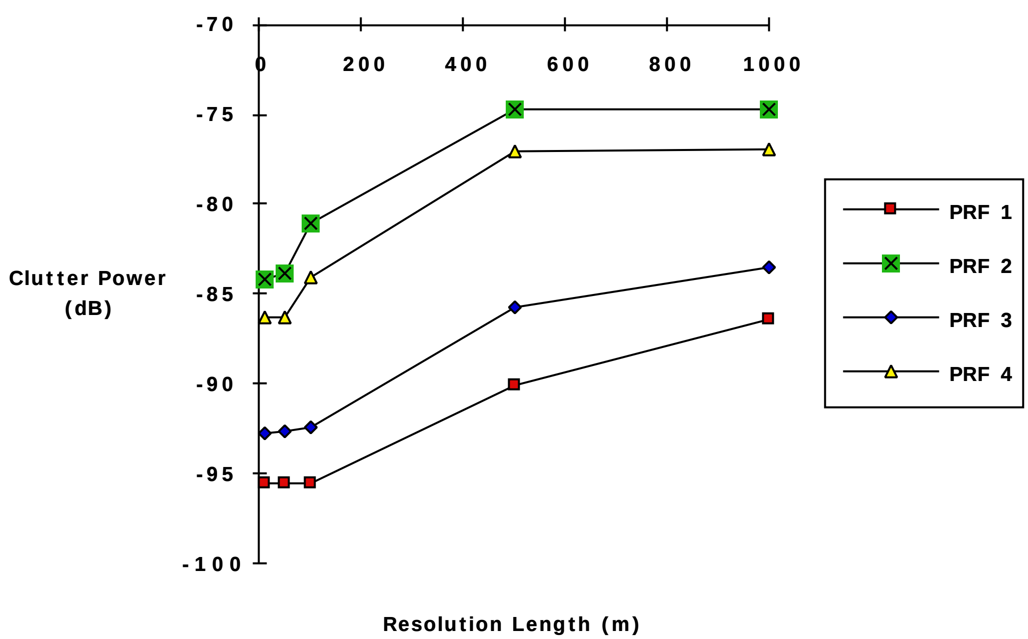

FIGURE 3.12-4. Clutter Power vs. Resolution Length
Target Altitude 61 m/Terrain Type = Grass.

Figure 3.12-5 compares clutter power computed as a function of altitude for three different terrain types. The clutter powers are consistent with the relative terrain reflectivities illustrated earlier. Clutter attenuation with altitude is a consequence of smaller antenna gain as the illuminated terrain patch moves to larger off-boresight elevation angles. The maxima and minima are a consequence of the sidelobe structure.

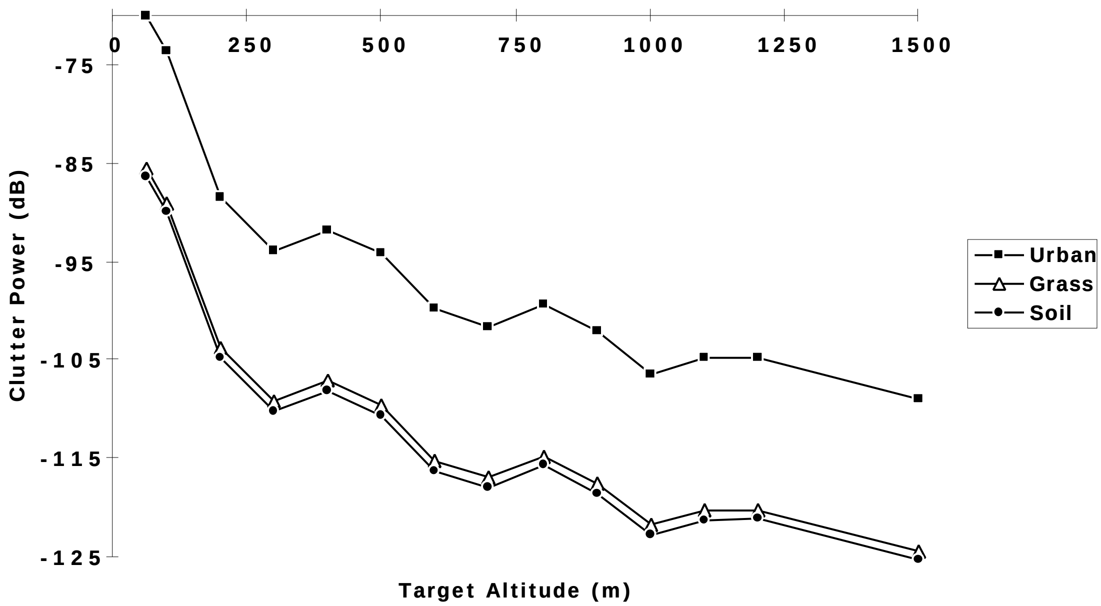

FIGURE 3.12-5. Clutter Power vs. Altitude for Different Terrain Types.

3.12.3 Conclusions

While trends of clutter calculations, as a function of resolution length and PRF, are as expected, power returned as a function of altitude and terrain types is very low. Given that maximum clutter power (-50dB) will occur at altitudes below 100m, the additional run-time required to compute it hardly seems worthwhile. Such low levels of clutter would only impact detection and tracking of very low RCS (<-20dB) targets.